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Export of L4S ECN in IP Flow Information Export (IPFIX)  
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## Abstract

This document defines a set of IP Flow Information Export (IPFIX) Information Elements for monitoring the Low Latency, Low Loss, and Scalable throughput (L4S) service. Specially, these elements enable network operators to monitor the Explicit Congestion Notification (ECN) information of L4S deployment and performance of traffic.

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## 1. Introduction

The Low Latency, Low Loss, and Scalable throughput (L4S) service, defined in [RFC9331], introduces a new network service that enables low latency and high throughput for traffic using Scalable congestion controls. To deploy and operate L4S effectively, network operators need visibility into L4S traffic patterns, performance metrics, and interoperability with existing traffic.

IP Flow Information Export (IPFIX) [RFC7011] provides a standard protocol for exporting flow information from network devices. This document defines a set of IPFIX Information Elements specifically designed for monitoring L4S ECN traffic.

These Information Elements are particularly useful during the experimental phase of L4S deployment as specified in [RFC9331], allowing operators to gather data to examine performance and identify nodes where remediation may be necessary to provide the best performance.

## 2. Terminology

### 2.1. Terms Used in This Document

This document makes use of the terms defined in [RFC9331], [RFC9330] and [RFC7011].

IPFIX: IP Flow Information Export

IPFIX Information Elements

Observation Point

L4S: Low Latency, Low Loss, and Scalable throughput (L4S) service

ECN: Explicit Congestion Notification

ECT: ECN-capable Transport

Not-ECT: Not ECN-capable transport

CE: Congestion Experienced

### 2.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

## 3. Overview of ECN Format

### 3.1. IPv4 ECN Field

For IPv4 packets, the ECN field is located in the Type of Service (TOS) byte of the IP header, specifically in bits 6 to 7. The definition for the IPv4 TOS octet (see [RFC791]) has been superseded by the six-bit DS (Differentiated Services) Field (see [RFC2474], [RFC2780]). Bits 6 and 7 are listed in [RFC2474] as Currently Unused, and are specified in [RFC2780] as approved for experimental use for ECN. The ECN field in IPv4 header is showed as follows.

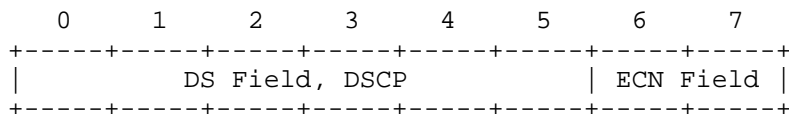


Figure 1: ECN Fields in IPv4

ECN Codepoint values:

00: Not ECT

01: ECT(0)

10: ECT(1)

11: CE

### 3.2. IPv6 ECN Field

For IPv6 packets, the ECN field is located in bits 6 to 7 of IPv6 Traffic Class. The definition for the IPv6 Traffic Class octet (see [RFC791]) has been superseded by the six-bit DS (Differentiated Services) Field (see [RFC2474], [RFC2780]). Bits 6 and 7 are listed in [RFC2474] as Currently Unused, and are specified in [RFC2780] as approved for experimental use for ECN. The ECN field in IPv6 header is showed as follows.

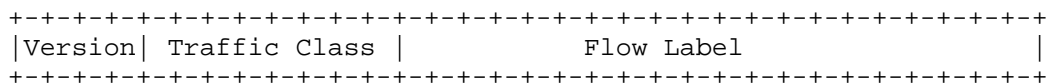


Figure 2: ECN Fields in IPv6

## 4. IPFIX Information Elements for L4S ECN Monitoring

This section defines the Information Elements for L4S ECN. These elements are intended for experimental use in L4S monitoring.

### 4.1. ipv4HeaderEcn

Name: ipv4HeaderEcn

ElementID: TBD1

Description: This element is used for capturing the complete ECN

state of each packet, enabling detailed analysis of congestion notification. The ECN field for IPv4 header is introduced in section 3.1 of this draft. L4S traffic is identified by the ECT(1) as specified in [RFC9331].

The Information Element encodes only these 2 bits. Therefore, its value may range from 0 to 3.

Abstract Data Type: unsigned8

Data Type Semantics: identifier

Additional Information: See [RFC2474] and [RFC2780] for IPv4 ECN field definition.

Reference: [RFC3168], [RFC9331], this document.

#### 4.2. ipv6HeaderEcn

Name: ipv6HeaderEcn

ElementID: TBD2

Description: This element is used for capturing the complete ECN state of each packet, enabling detailed analysis of congestion notification. The ECN field format is introduced in section 3.2 of this draft. L4S traffic is identified by the ECT(1) codepoint as specified in [RFC9331].

The Information Element encodes only these 2 bits. Therefore, its value may range from 0 to 3.

Abstract Data Type: unsigned8

Data Type Semantics: identifier

Additional Information: See [RFC2474] and [RFC2780] for IPv6 ECN field definition.

Reference: [RFC3168], [RFC9331], this document.

#### 4.3. mplsHeaderEcn

Name: mplsHeaderEcn

ElementID: TBD3

Description: The EXP field of the MPLS label header is used for

carring ECN information in the MPLS domain. As recommended in [RFC5129], explicit congestion notification in MPLS should use codepoints in the EXP field.

The Information Element encodes only these 3 bits. Therefore, its value may range from 0 to 7.

It is noted that the information extraction of this information element is only used when the MPLS domain has ECN support.

Abstract Data Type: unsigned8

Data Type Semantics: identifier

Additional Information: see [RFC5129] for detailed information for MPLS ECN tunnel negotiation.

Reference: [RFC5129], this document.

#### 4.4. ipsecSaEcnMode

Name: ipsecSaEcnMode

ElementID: TBD4

Description: The information element indicates whether ECN functionality is allowed for an IPsec Security Association (SA) in tunnel encapsulation mode. The IPsec SA Attribute value 10 is defined for ECN tunnel negotiation as defined in section 9.2.1 of [RFC3168]. The negotiation value includes allowed (value set 1) and forbidden (value set 2) attribute. The allowed value enables ECN congestion notifications and the forbidden value disables such notifications.

Abstract Data Type: unsigned8

Data Type Semantics: identifier

Additional Information: See [RFC3168] for detailed information for IPsec tunnel ECN negotiation.

Reference: [RFC5129], this document.

#### 4.5. l2tpEcnNego

Name: l2tpEcnNego

ElementID: TBD5

Description: For L2TP tunnels, ECN processing is performed at the L2TP encapsulation layer. [RFC9601] defines an ECN Capability AVP (Type 103) for negotiation between L2TP Control Connection Endpoints. The presence of this AVP indicates support for ECN propagation.

Abstract Data Type: unsigned16

Data Type Semantics: identifier

Additional Information: See [RFC9601] for detailed information for L2TP tunnel ECN negotiation.

Reference: [RFC5129], this document.

#### 4.6. notEctPacketDeltaCount

Name: notEctPacketDeltaCount

ElementID: TBD6

Description: The number of packets since the previous report (if any) in this Flow with ECN codepoint set to Not-ECT (binary 00).

Abstract Data Type: unsigned64

Data Type Semantics: deltaCounter

Additional Information: Refer to [RFC9331].

Reference: [RFC3168], [RFC9331], this document.

#### 4.7. notEctPacketTotalCount

Name: notEctPacketTotalCount

ElementID: TBD7

Description: The total number of packets of this Flow with ECN codepoint set to Not-ECT at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

Additional Information: Refer to [RFC9331].

Reference: [RFC3168], [RFC9331], this document.

#### 4.8. ect0PacketDeltaCount

Name: ect0PacketDeltaCount

ElementID: TBD8

Description: The number of packets since the previous report (if any) in this Flow with ECN codepoint set to ECT(0) (binary 01).

Abstract Data Type: unsigned64

Data Type Semantics: deltaCounter

Additional Information: Refer to [RFC3168].

Reference: [RFC3168], [RFC9331], this document.

#### 4.9. ect0PacketTotalCount

Name: ect0PacketTotalCount

ElementID: TBD9

Description: The total number of packets of this Flow with ECN codepoint set to ECT(0) at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

Additional Information: Refer to [RFC3168].

Reference: [RFC3168], [RFC9331], this document.

#### 4.10. ect1PacketDeltaCount

Name: ect1PacketDeltaCount

ElementID: TBD10

Description: The number of packets since the previous report (if any) in this Flow with ECN codepoint set to ECT(1) (binary 10).

Abstract Data Type: unsigned64



Data Type Semantics: deltaCounter

Additional Information: Refer to [RFC3168].

Reference: [RFC3168], [RFC9331], this document.

#### 4.11. ect1PacketTotalCount

Name: ect1PacketTotalCount

ElementID: TBD11

Description: The total number of packets of this Flow with ECN codepoint set to ECT(1) at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

Additional Information: Refer to [RFC9331].

Reference: [RFC3168], [RFC9331], this document.

#### 4.12. cePacketDeltaCount

Name: cePacketDeltaCount

ElementID: TBD12

Description: The number of packets since the previous report (if any) in this Flow with ECN codepoint set to CE (Congestion Experienced, binary 11).

Abstract Data Type: unsigned64

Data Type Semantics: deltaCounter

Additional Information: Refer to [RFC9331].

Reference: [RFC3168], [RFC9331], this document.

#### 4.13. cePacketTotalCount

Name: cePacketTotalCount

ElementID: TBD13

Description: The total number of packets of this Flow with ECN codepoint set to CE at the Observation Point since the Metering Process (re-)initialization for this Observation Point.

Abstract Data Type: unsigned64

Data Type Semantics: totalCounter

Additional Information: Refer to [RFC9331].

Reference: [RFC3168], [RFC9331], this document.

## 5. Operational Considerations

The IPFIX IEs defined in this draft may have their information extraction positions adjusted based on different ECN monitoring purposes in the network. Among them, the basic ECN field elements are used to reflect the ECN codepoints carried in the IPv4 header, the IPv6 header, or the MPLS header. These fields can be flexibly extracted at any node along the path that has IPFIX export capability. For tunnel ECN negotiation status IEs, the IPFIX data can only be provided by the specific tunnel endpoints that participate in the negotiation. For cumulative statistics IEs, the statistical data may be processed with a higher priority at traffic aggregation or egress nodes.

In L4S deployments, CE marking may be either probabilistic or deterministic, as determined by the specific AQM implementation. The IEs on the statistical count of CE-mark packets is defined to enable operators to perform quantitative monitoring and management of L4S service performance, typically based on flow data that may be acquired via packet or flow sampling. Implementations should employ sampling methods (see [RFC5475]) that preserve the statistical representativeness of these IEs and reduce bias risk of sampling results.

For IPsec tunnels, monitoring ECN requires exporting both outer and inner IP header ECN fields (ipHeaderOuterEcn and ipHeaderInnerEcn), along with ipsecSaEcnMode (see section 4.4 of this draft). Relying solely on the outer IP header ECN field may be insufficient, as it could be set to Not ECT due to tunnel mode restrictions. Similarly, for L2TP tunnels, ECN monitoring should be verified the l2tpEcnNego element (see section 4.5) except the ECN information extraction from tunnel outer header and inner header of packets.

For MPLS tunnels, the ECN handling mechanism differs fundamentally from IP based tunnels. ECN information is not carried in a dedicated IP header field but is encoded within the MPLS label stack using the

EXP field, as defined in [RFC5129]. Therefore, monitoring ECN over MPLS requires exporting the `mplsHeaderEcn` element defined in Section 4.3 of this draft. This element captures the congestion indication as conveyed within the MPLS domain, which is independent of the inner IP packet's ECN field.

The calculation of derived metrics (e.g., L4S CE marking ratios) from the base counters defined in the section 4 of this draft is an implementation issue for the IPFIX Collector. Operators can utilize the per-flow counts such as `ect1PacketTotalCount` and `cePacketTotalCount` for such purposes. The calculation strategy is out of the scope of this draft.

## 6. Security Considerations

The security considerations for IPFIX [RFC7011] apply to this document. The elements for ECN reveal information about endpoint ECN capabilities. Although the information may generally be not sensitive, operators should consider applicable privacy regulations. IPFIX records containing L4S monitoring information SHOULD be transported using secure protocols such as TLS or DTLS and satisfy the mutual authentication between IPFIX Exporting Processes and IPFIX Collecting Processes as specified in [RFC7011].

## 7. IANA Considerations

IANA is requested to assign the following Information Elements in the IPFIX Information Elements registry.

Element ID	Name	Reference
TBD1	IPv4HeaderEcn	This document
TBD2	IPv6HeaderEcn	This document
TBD3	MPLSHeaderEcn	This document
TBD4	ipsecSaEcnMode	This document
TBD5	l2tpEcnNego	This document
TBD6	notEctPacketDeltaCount	This document
TBD7	notEctPacketTotalCount	This document
TBD8	ect0PacketDeltaCount	This document
TBD9	ect0PacketTotalCount	This document
TBD10	ect1PacketDeltaCount	This document
TBD11	ect1PacketTotalCount	This document
TBD12	cePacketDeltaCount	This document
TBD13	cePacketTotalCount	This document

Table 1: New IPFIX Information Elements

## 8. References

### 8.1. Normative References

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[RFC9601] Briscoe, B., "Propagating Explicit Congestion Notification across IP Tunnel Headers Separated by a Shim", RFC 9601, DOI 10.17487/RFC9601, August 2024, <<https://www.rfc-editor.org/info/rfc9601>>.

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